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Social Cognition and Social Functioning in MCI and Dementia in an Epidemiological Sample

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Abstract

Objective: Social cognition is impaired in mild cognitive impairment (MCI) and dementia. However, its relationship to social functioning and perceived social support has yet to be explored. Here, we examine how theory of mind (ToM) relates to social functioning in MCI and dementia. **Methods:** Older adults (cognitively normal = 1272; MCI = 132; dementia = 23) from the PATH Through Life project, a longitudinal, population-based study, were assessed on the Reading the Mind in the Eyes Test (RMET), measures of social functioning, and social well-being. The associations between RMET performance, social functioning, and cognitive status were analysed using generalised linear models, adjusting for demographic variables. **Results:** Participants with MCI (b=−.52, 95% CI [−.70, −.33]) and dementia (b=−.78, 95% CI [−1.22, −.34]) showed poorer RMET performance than cognitively normal participants. Participants with MCI and dementia reported reduced social network size (b=−.21, 95% CI [−.40, −.02] and b=−.90, 95% CI [−1.38, −.42], respectively) and participants with dementia reported increased loneliness (b = .36, 95% CI [.06, .67]). In dementia, poorer RMET performance was associated with increased loneliness (b=−.07, 95% CI [−.14, −.00]) and a trend for negative interactions with partners (b=−.37, 95% CI [−.74, .00]), but no significant associations were found in MCI. **Conclusions:** MCI and dementia were associated with poor self-reported social function. ToM deficits were related to poor social function in dementia but not MCI. Findings highlight the importance of interventions to address social cognitive deficits in persons with dementia and education of support networks to facilitate positive interactions and social well-being.

Keywords: Dementia, MCI, Social functioning, Social cognition, Theory of mind, Cohort study

Social cognition, the ability to recognise and respond to socially relevant information (Kennedy & Adolphs, 2012), underlies social behaviour and functioning and is critical for interpreting the social world (Kunda, 1999). Theory of mind (ToM), in particular, is a key component that refers to the capacity to understand others' thoughts and beliefs (Henry, Phillips, Ruffman, & Bailey, 2013). Social cognition and ToM have typically been explored in the context of developmental, neurological, and psychiatric disorders including autism spectrum disorder (Kennedy & Adolphs, 2012), but relatively little is known about these abilities in the context of ageing and late-life cognitive disorders like dementia.

Dementia is a clinical syndrome with a range of possible aetiologies, all of which involve severe cognitive and behavioural impairments that affect function. Mild cognitive impairment (MCI) is considered an intermediate state of cognitive decline between normal, age-related decline and dementia, with minimal to no impact on day to day function (Winblad et al., 2004). MCI can be classified into four different subtypes depending on whether it affects memory (amnestic or non-amnestic) and whether the impairment affects multiple areas of cognition (single or multi-domain). Dementia is considered a more severe stage of cognitive impairment that has substantial impact on daily activities, and according to some definitions, requires deficits in memory, as well as an additional domain of cognition (Knopman & Petersen, 2014). More recent definitions (American Psychiatric Association, 2013) retain the distinction between MCI and dementia in terms of level of impairment and functional impact, but with reduced emphasis on memory impairment, and a broader range of cognitive domains to consider – including social cognition as a distinct domain with defined neural correlates (Schurz et al., 2020). This provides an opportunity to better characterise the impact of ageing and neurodegenerative disorders on social function.

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There is increasing evidence that performance on tests of social cognition is impaired with normal ageing (Beadle & de la Vega, 2019; Henry et al., 2013), MCI (Bora & Yener, 2017; McCade, Savage, & Naismith, 2011; Spoletini et al., 2008) and dementia syndromes (Bora, Walterfang, & Velakoulis, 2015). Impaired social cognition is most prominent in behavioural variant frontotemporal dementia (FTD) and has been extensively examined in the context of this syndrome (Brioschi Guevara et al., 2015; Rankin, 2020). Social cognition and ToM impairments are also apparent to a lesser degree in people with Alzheimer's disease (AD) pathology (Bora et al., 2015). Given that both FTD and AD are relatively common syndromes of late-life dementia – particularly AD which is the most common dementia pathology in most populations (Plassman et al., 2007; Tang et al., 2001) – impaired social cognition potentially plays a significant role in the daily functioning of older adults with dementia. These deficits may emerge at pre-dementia stages. Meta-analyses have shown significant ToM impairments in MCI, with pooled effect sizes of approximately $d = .65$ (Bora & Yener, 2017; Yi et al., 2020). In addition, different subtypes of MCI are differentially impaired, with emotion recognition reported to be more impaired in multi-domain amnestic MCI than in single-domain amnestic MCI (Bora & Yener, 2017). Relative to MCI, ToM appears to be more impaired in dementia, with effect sizes of over $d = 1.10$ in AD and over $d = 1.70$ in FTD (Bora et al., 2015; Yi et al., 2020).

Despite evidence that MCI and dementia are associated with impaired performance on tests of social cognition, its impact on everyday social functioning is understudied. Prior studies have examined the relationship between social cognition and social functioning in other clinical and non-clinical populations. For example, impaired ToM is linked to poorer social skills and communication in people with autism (Frith, 1994; Peterson, Garnett, Kelly, & Attwood, 2009) and in cognitively healthy older adults (Bailey, Henry, & Von Hippel, 2008). In addition, individuals who attempt suicide in later life demonstrate poorer ToM along with smaller social networks and disrupted interpersonal relationships (Szanto et al., 2012). On the other hand, a study of cognitively healthy older men found that better performance on a ToM Faux Pas test was associated with smaller close social networks and reduced loneliness (Radecki, Cox, & MacPherson, 2019).

Impaired social function in MCI and dementia is likely to be multifactorial with clinical, psychological, and socio-demographic factors implicated in addition to social cognition. Late-life factors contributing to reduced social networks or loneliness include low socio-economic status, poor health, female gender, and widowhood (Hansen & Slagsvold, 2016). Both cognitive decline and social network size in late life have been linked to depression and anxiety (Yates, Clare, & Woods, 2017) as well as personality factors such as neuroticism (McHugh Power, Lawlor, & Kee, 2017). Social behaviour in MCI and early dementia is also linked to impairments in verbal memory (Henry et al., 2012). Some of these factors can also confound the measurement of ToM. For example, many tests of ToM require verbal responding which is influenced by language disturbance, proficiency, or low education (Olderbak et al., 2015). Tests reliant on images of facial expressions, such as the widely used Reading the Mind in the Eyes Test (RMET), although well characterised, lack diversity in its stimulus bank and are confounded by other race effects on face processing (Adams et al., 2010; Dodell-Feder, Ressler, & Germine, 2020). There is also evidence of a gender difference with women outperforming men on some measures (Kirkland, Peterson, Baker, Miller, & Pulos, 2013).

Importantly, the relationship between dementia and social engagement is bidirectional. Low social engagement and negative social support are key risk factors for dementia (Khondoker, Rafnsson, Morris, Orrell, & Steptoe, 2017; Penninkilampi, Casey, Singh, & Brodaty, 2018). Further, people with dementia tend to experience reduced social engagement in years following dementia diagnosis (Hackett, Steptoe, Cadar, & Fancourt, 2019). Nevertheless, identifying links between social cognition and function, particularly in at-risk groups such as MCI, is necessary because of its potential to inform management and risk reduction strategies. For example, if difficulties with social engagement co-occur with impaired social cognition, this may warrant strategies to compensate for these impairments when encouraging greater social activity as a dementia risk reduction intervention.

In this study, cross-sectional associations between ToM performance and social functioning were examined using the RMET in an epidemiological sample of older adults composed of cognitively normal individuals and individuals diagnosed with MCI and dementia (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). Dementia and MCI were defined according to DSM-IV (American Psychiatric Association, 2000) and International Working Group (Winblad et al., 2004) criteria, respectively, and given the population-based nature of the sample, included all causes of dementia with a likely greater prevalence of AD-type. It was hypothesised that (1) individuals with MCI and dementia would show poorer RMET performance, (2) multi-domain MCI would show larger RMET deficits than single-domain amnestic MCI, (3) individuals with MCI and dementia would have poorer social functioning, and (4) that poorer RMET performance in MCI and dementia would be associated with poorer social functioning.

METHODS

PARTICIPANTS

Participants were drawn from the Personality and Total Health (PATH) Through Life project, a longitudinal, population-based study. Cohort characteristics are covered in previous publications (see Anstey et al., 2012 for overview). In summary, Canberra and Queanbeyan residents aged within three cohorts (20–24, 40–44, 60–64 years) were randomly sampled from the electoral roll. Electoral enrolment is compulsory for all Australian citizens over 18 years old.

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Participants were followed approximately every 4 years and completed a broad range of demographic, lifestyle, physical, and psychological health measures. This study focusses on the oldest cohort (60s, aged 72–76 years) at Wave 4 ($n = 1{,}645$) who at this time received diagnoses of MCI (Winblad et al., 2004) and dementia (according to DSM-IV; American Psychiatric Association, 2000). Wave 1 included 2,551 participants in the 60s and retention rates were high (over 85%) between waves. Figure 1 shows the participant flow chart for the 60s. The inclusion criterion was completion of the RMET; however, participants diagnosed with other dementias that did not meet DSM-IV criteria ($n = 37$) were excluded. The final sample included 1,427 participants, classified as cognitively normal ($n = 1{,}272$), diagnosed with MCI ($n = 132$) or dementia ($n = 23$). Of those diagnosed with dementia, the pathology was 87% AD, 4% vascular, and 9% Parkinson's disease. The study protocol was approved by the Australian National University's Human Research Ethics Committee. The research was conducted in compliance with institutional research standards and with the Helsinki Declaration.

Diagnosis

Research diagnoses of dementia (DSM-IV) and MCI (Winblad et al., 2004) were completed in two stages (see Eramudugolla et al., 2017). First, an algorithm was used to screen potentially impaired participants based on scores on a neurocognitive test battery, informant rating scales, and survey data on medical and psychiatric history. A neurologist then reviewed each participant's case file to determine diagnosis. Performance on the RMET was not considered in the diagnoses of MCI and dementia.

Procedures

Social cognition was measured as part of a battery of standardised cognitive tests (including memory, attention, processing speed, and executive function) during a face-to-face interview with a trained interviewer, typically conducted at the participant's home. Social functioning measures were administered as part of a self-completed online survey including psychological health and well-being scales. The face-to-face interview and online survey were conducted within a few months of each other. Participants' instrumental activities of daily living (measured with Bayer-ADL scale; Hindmarch, Lehfeld, de Jong, & Erzigkeit, 1998), medical, and psychological history were also collected via telephone interviews from informants (family member, friend, or spouse).

Measures

Reading the Mind in the Eyes Test (Revised)

The RMET test (Baron-Cohen et al., 2001) is an advanced test of ToM and requires recognition of complex emotions from eye regions (Baron-Cohen et al., 2015; Baron-Cohen et al., 2001). It has internal consistency of $\alpha = .61$ and test–retest reliability of ICC = .83 (95% CI [.75 to .90] Fernández-Abascal, Cabello, Fernández-Berrocal, & Baron-Cohen, 2013; Vellante et al., 2013) and is able to effectively distinguish between typical populations and populations with autism spectrum disorder and schizophrenia (Baron-Cohen et al., 2015; de Achával et al., 2010). Participants were presented with a photo of the eye region and asked to match the emotion of the person in the photo to one of four possible verbal descriptors (e.g., jealous, panicked, arrogant, hateful). A glossary of definitions of each word was provided for reference during the test. Participants were encouraged to guess when unsure. A total of 36 items were presented, with each item scored as correct or incorrect. The test was scored out of 36, with lower scores indicating poorer performance.

Demographic and personality measures

Self-reported level of education (total years), gender (male/female), and racial background (Caucasian/non-Caucasian) were collected via survey. Neuroticism was measured using the Eysenck Personality Questionnaire, which produced a score out of 25 (Eysenck & Eysenck, 1975).

Social functioning measures

The social functioning measures include the Lubben Social Network Scale (Lubben et al., 2006), Schuster Social Support Scales (Schuster, Kessler, & Aseltine, 1990), and the three-item Loneliness Scale (Hughes, Waite, Hawkley, & Cacioppo, 2004). The Lubben Social Network Scale (Lubben et al., 2006) contains six items on relationships with family and friends (e.g. "how many relatives do you see or hear from at least once a month?"), with each item scored between 0 and 5. The total score was out of 30, with higher scores indicating more social engagement. The Schuster Social Support Scale includes 20 items on positive and negative support received from family, friends, and spouses (e.g. "How often do they criticize you?"), with items scored between 0 (Often/A lot) and 4 (Never/Not at all). Higher scores on positive scales and lower scores on negative scales suggest increased support. The 3-item Loneliness Scale assesses subjective loneliness by rating questions (e.g. "how often do you feel left out?") between 1 (Hardly ever) and 3 (Often). Total score ranged from 3 to 9, with higher scores suggesting greater loneliness.

Missing Data Approach

Missing data were managed through Predictive Mean Matching multiple imputation ($n = 5$) in SPSS with seed set at 1000. RMET scores were not imputed.

Data Analysis

Analyses used generalized linear models (GLM) with robust estimation in SPSS ver. 25. Scores on RMET and social

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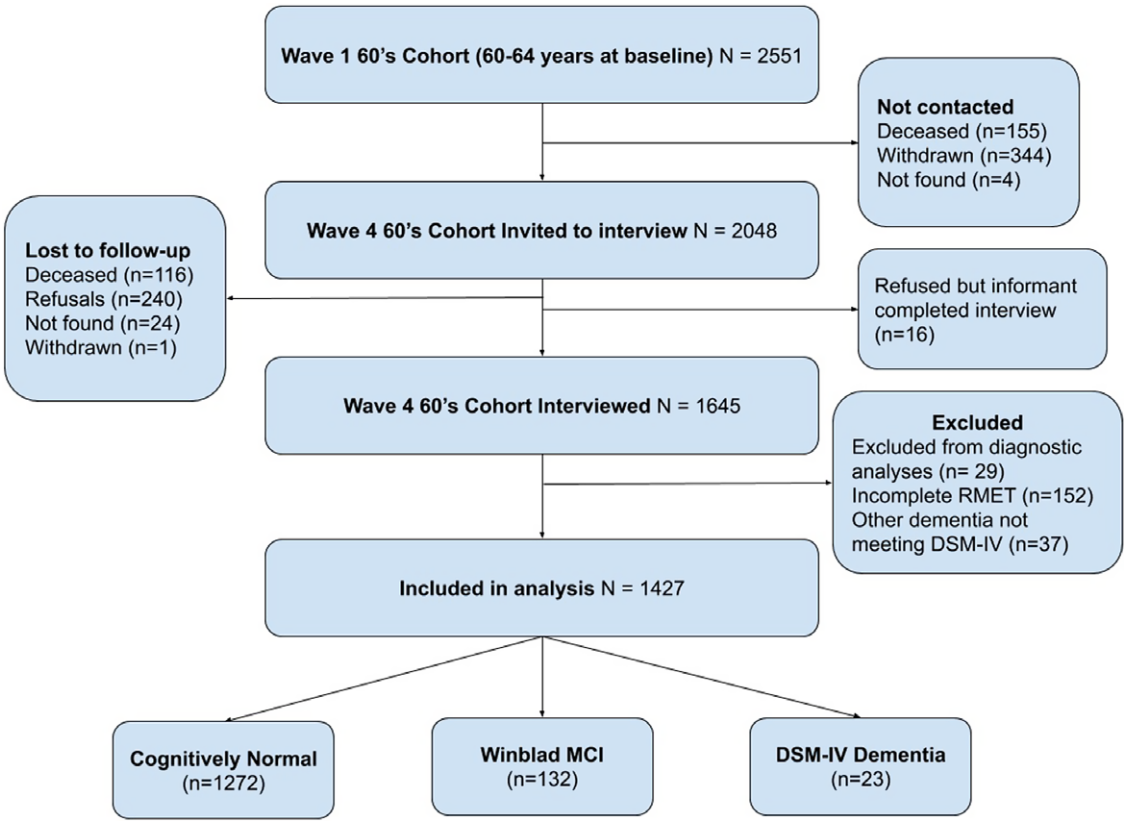

Figure 1. Flow chart of participants from the PATH Through Life project included in current study.

functioning scales were converted to *z*-scores for analyses relative to the entire PATH sample data at Wave 4. To examine RMET performance in dementia and MCI, Model 1 included diagnosis (dementia and MCI, with the cognitively healthy control group as a reference) as a predictor of RMET *z*-scores, without covariates. Model 2 additionally adjusted for gender, years of education, and race (Caucasian vs non-Caucasian). These covariates that were included as gender, education level, and race have been previously associated with dementia risk and RMET scores. In particular, dementia is more prevalent in females than in males (Plassman et al., 2007), and lower education level (Sharp & Gatz, 2011) and non-Caucasian background (Tang et al., 2001) are associated with higher risk of dementia. Higher RMET scores are also associated with female gender (Kirkland et al., 2013), higher education, and Caucasian background (Dodell-Feder et al., 2020). Age was not included as a covariate because of the narrow age range of the cohort. Model 3 included diagnosis (dementia and MCI subtypes [amnestic single domain, amnestic multi-domain, non-amnestic]) as a predictor of RMET z-scores, adjusting for the above covariates.

To examine the association between social functioning, diagnosis, and RMET *z*-scores, Models 4 to 9 included RMET *z*-scores and RMET x Diagnosis interaction effects as predictors of *z*-scores on the social functioning scales, adjusting for gender, years of education, race (Caucasian vs non-Caucasian), and neuroticism. Besides controlling for gender, education, and race for reasons stated above, neuroticism was also controlled for in these analyses because it has been found to affect interpretation of social stressors and interactions (Denissen & Penke, 2008) and is associated with increased risk of cognitive decline (Ayers, Gulley, & Verghese, 2020). Analyses of partner social support were limited to cases that reported living with their partner. Scores on the Lubben Social Network scale and negative support scales for friend, family, and partner were relatively symmetrically distributed or showed a small positive skew (.5 to −.2). Scores on the loneliness scale were positively skewed (1.54), and scores on all positive support scales were negatively skewed (−1.7 to −2.4). Scores on the positive social support scales were reflected for analysis such that higher scores represented less positive social support. All standardised positively skewed outcome variables were shifted to have a positive range, mean-centred, and analysed using GLMs with a gamma distribution and log link function. Separate, fully adjusted GLM models were run predicting the *z*-scores for Social Network size, Loneliness, and each dimension of the Social Support scale (positive and negative for family, friend, and partner).

RESULTS

Participant Characteristics

Demographic, cognitive, and psychological variables were comparable between the original data set and the pooled

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imputed data set (data not shown). Table 1 presents descriptive data on the participants according to cognitive status (cognitively normal, MCI and dementia).

Associations Between Diagnostic Category and RMET Performance

Table 2 demonstrates associations between cognitive status, demographic variables, and RMET performance. The pattern of results was similar in analyses using complete cases (Table 2) and following multiple imputation to adjust for missing values (Table 3). In Model 1, individuals with MCI performed .52 *SD*, 95% CI [−.70, −.33] worse on the RMET than cognitively normal individuals, while those with dementia performed .74 *SD*, 95% CI [−1.13, −.34] worse than cognitively normal participants. The effect of MCI on RMET performance reduced to .39 *SD*, 95% CI [−.56, −.22] in Model 2 after controlling for demographic factors (gender, age, years of education and racial background). Male gender, non-Caucasian racial background, and fewer years of education were all independently associated with poorer RMET performance.

Associations Between MCI Subtype and RMET Performance

Table 3 depicts the associations between MCI subtype and RMET performance after controlling for demographic variables. The pattern of results was similar in analyses using complete cases and in analyses with imputed values. Individuals with amnestic multi-domain MCI and non-amnestic MCI performed significantly worse (on average .44 and .47 *SD* worse, respectively) on RMET compared to cognitively normal participants. Individuals with amnestic single-domain MCI did not significantly differ from cognitively normal participants in RMET performance.

Associations Between Diagnostic Category, RMET Performance, and Measures of Social Function

Separate fully adjusted linear models were conducted to show the associations between diagnostic category, RMET performance, and measures of social function (Table 4). Models included interactions between diagnostic category and RMET performance. The effect sizes did not differ after being adjusted for demographic variables. Relative to cognitively normal participants, those with MCI or dementia had significantly reduced social network size ($b = -.21$, 95% CI [−.40, −.02] and $b = -.90$, 95% CI [−1.38, −.42], respectively). Dementia was also associated with increased subjective reports of loneliness ($b = .36$, 95% CI [.06, .67]). RMET performance within MCI was not associated with any measure of social function. RMET performance within dementia was associated with social functioning, such that higher RMET scores were associated with less perceived loneliness ($b = -.07$, 95% CI [−.14, −.00]), and a trend towards less negative social interaction with partners ($b = -.37$, 95% CI [−.74, .00]) among participants living with a partner. In all models, RMET scores were not independently associated with any social functioning measure. Neuroticism was associated with all measures of social functioning. Females (relative to males) had greater social network size, fewer negative and more positive friend interactions, but fewer positive partner interactions. Non-Caucasian background was associated with greater perceived loneliness and more negative and fewer positive partner interactions. In general, the models overall explained a small degree of variance (5–10%) in the outcome measures.

DISCUSSION

To our knowledge, this is the first study to investigate ToM performance and its associations with social functioning in MCI and dementia in a population-based sample. We found poorer RMET performance in older adults with MCI and dementia compared to cognitively healthy participants. Furthermore, poorer RMET performance was found in multi-domain amnestic and non-amnestic MCI, but not single-domain amnestic MCI. Diagnoses of MCI and dementia were associated with reduced social network size, and a diagnosis of dementia was additionally associated with increased loneliness. In dementia, but not MCI, poorer RMET performance was associated with poorer social functioning, specifically greater loneliness and more negative social interactions with partners.

People with MCI and dementia showed poorer RMET performance compared to cognitively normal participants, as hypothesised. This is consistent with previous studies of ToM in MCI and dementia (Bora et al., 2015; Bora & Yener, 2017; Moreau et al., 2015; Yi et al., 2020). These observed deficits may at least partly reflect neurodegeneration in regions implicated in ToM, such as the medial prefrontal cortex, temporo-parietal junction, insula, and anterior cingulate cortex (Beadle & de la Vega, 2019; Schurz et al., 2020). In the cognitively healthy group, mean performance ($M = 21.18$, $SD = 4.21$) was low relative to scores reported for healthy adults in the literature (range: 26–28) (Baron-Cohen et al., 2001; Pardini et al., 2013; Peñuelas-Calvo, Sareen, Sevilla-Llewellyn-Jones, & Fernández-Berrocal, 2019)}. Given the age of the sample in this study (72–76 years), the findings are consistent with emerging evidence of age-related decline in RMET performance (Kynast et al., 2020), tests of emotional intelligence (Cabello, Navarro, Latorre, & Fernández-Berrocal, 2014), empathy (Beadle & de la Vega, 2019), and other tests of ToM (Baksh, Abrahams, Auyeung, & MacPherson, 2018; Henry et al., 2013). For example, one study has demonstrated significant age-related decline of around .3 standard deviations in RMET performance in a population-based sample of adults aged 19 to 79 years without neurological impairment (Kynast et al., 2020). The predicted RMET performance

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Table 1. Sample characteristics

Variable	Cognitively normal		MCI		Dementia[b]	
	$n = 1272$		$n = 132$		$n = 23$	
	M	*SD*	*M*	*SD*	*M*	*SD*
Demographic						
Age	75.04	1.49	75.21	1.64	75.87	1.33
Years of education	14.48	2.47	13.56	2.82	14.09	2.95
Female gender[a]	627	49.3%	61	46.2%	9	39.1%
Non-Cauc. background[a]	31	2.4%	9	6.8%	0	0%
Cognitive/Psychological						
RMET-R	21.18	4.21	18.95	4.48	17.83	4.74
Goldberg Depression	1.46	1.67	2.02	1.98	2.22	2.26
EPQ Neuroticism	3.01	2.81	3.74	2.29	2.96	2.88
Attention (*z*-score)	.02	.45	−.11	.75	.01	.78
Memory (*z*-score)	.16	.54	−.46	.62	−1.41	.92
Language (*z*-score)	.13	.71	−.51	.72	−1.16	.83
Executive Function (*z*-score)	.05	.41	−.32	.47	−.46	.54
Perceptual/Motor (*z*-score)	.04	.55	−.27	.64	−.38	.70
Functional and Social						
Bayer IADLs score	1.72	.89	1.80	.73	4.28	1.59
Loneliness scale	3.91	1.33	4.10	1.53	4.35	1.67
Lubben S.N score	18.70	4.81	17.22	5.66	14.52	4.88
Schuster Social Support scales						
Friend positive	5.46	.89	5.33	.95	4.87	1.42
Friend negative	2.78	1.54	2.84	1.83	2.36	2.13
Family positive	5.52	.93	5.49	.95	5.57	.73
Family negative	3.17	1.86	3.21	2.08	2.86	2.10
Partner positive	13.47	2.37	13.38	2.52	13.94	1.18
Partner negative	4.98	2.97	5.36	3.32	5.67	2.69

Note. MCI = mild cognitive impairment, RMET = Reading the Mind in the Eyes test, EPQ = Eysenck Personality Questionnaire, IADL = instrumental activities of daily living, S.N = Social Network. Attention domain (mean *z*-score of Symbol Digits Modalities Test, Trails A, Choice Reaction Time); Memory domain (mean *z*-score of California Verbal Learning Test, Benton Visual Retention Test [Administration B]); Language domain (mean *z*-score of Controlled Oral Word Association Test, Boston Naming Test-15); Executive Function domain (mean *z*-score of Digit Span Backwards, Trails B, Stroop, Zoo Map sequence and error, Game of Dice Test safe choices); Perceptual/Motor domain (mean *z*-score of Purdue Pegboard, Ideomotor Apraxia Test, Benton Visual Retention Test [Administration C]).

[a]Female gender and non-Caucasian background presented as frequency (%). [b]Dementia aetiologies were as follows: Alzheimer's disease (n = 20 (87%)), vascular dementia (n = 1 (4%)), and Parkinson's disease (n = 2 (9%)).

Table 2. Associations between diagnostic category and RMET performance

Variable	Original data set				Pooled imputed data set			
	b	*SE*	95% CI	*p*	*b*	*SE*	95% CI	*p*
Model 1 – unadjusted								
MCI (ref: cognitively normal)	**−.52**	**.09**	**−.70, −.33**	**<.001**				
Dementia (ref: cognitively normal)	**−.78**	**.23**	**−1.22, −.34**	**.001**				
Model 2 – adjusted								
MCI (ref: cognitively normal)	**−.39**	**.09**	**−.56, −.22**	**<.001**	**−.39**	**.09**	**−.56, −.22**	**<.001**
Dementia (ref: cognitively normal)	**−.74**	**.20**	**−1.13, −.34**	**<.001**	**−.74**	**.20**	**−1.13, −.34**	**<.001**
Female gender (ref: male)	.15	.05	.05, .25	.003	.15	.05	.05, .25	.003
Years of education	.10	.01	.08, .12	<.001	.10	.01	.08, .12	<.001
Racial background (ref: Caucasian)	−.68	.15	−.98, −.38	<.001	−.68	.15	−.98, −.38	<.001

Note. MCI = mild cognitive impairment, RMET = Reading the Mind in the Eyes test. No imputation needed for Model 1 (unadjusted); For Model 2 (adjusted), original $N = 1425$ (1270 cognitively normal, 23 dementia, 132 MCI), and pooled $N = 1427$ (1272 cognitively normal, 132 MCI, 23 dementia).

Table 3. Associations between MCI subtype and RMET (*z*-score) performance adjusted

Variable	Original data set ($n = 1425$)[a]			Pooled imputed data set ($n = 1427$)[b]		
	b	95% CI	*p*	*b*	95% CI	*p*
MCI subtype (ref: cognitively normal)						
MCI-amnestic single domain	**−.26**	**−.54, .03**	**.08**	**−.26**	**−.54, .03**	**.08**
MCI-amnestic multi-domain	**−.44**	**−.73, −.15**	**.003**	**−.44**	**−.73, −.15**	**.003**
MCI-non-amnestic	**−.47**	**−.76, −.19**	**.001**	**−.47**	**−.76, −.19**	**.001**
Dementia (ref: cognitively normal)	**−.74**	**−1.13, −.34**	**<.001**	**−.74**	**−1.13, −.35**	**<.001**
Female gender (ref: male)	.15	.05, .25	.003	.15	.05, .25	.003
Years of education	.10	.08, .12	<.001	.10	.08, .12	<.001
Racial background (ref: Caucasian)	−.68	−.98, −.38	<.001	−.68	−.98, −.38	<.001

Note. MCI = mild cognitive impairment, RMET = Reading the Mind in the Eyes test.
[a]Original: $N = 1425$ (1270 cognitively normal, 23 dementia, 45 MCI-non-amnestic, 43 MCI-amnestic multi-domain, 44 MCI-amnestic single domain);
[b]Imputed: $N = 1427$ (1272 cognitively normal, 23 dementia, 45 MCI-non-amnestic, 43 MCI-amnestic multi-domain, 44 MCI-amnestic single domain).

based on their study for healthy adults aged in their 70s (60–62% accuracy) aligns with the score range for our control group (58% accuracy). However, age effects could not be examined within the PATH cohort in the present study due to its narrow age range (4 years).

Within MCI, multi-domain amnestic and non-amnestic, but not single-domain amnestic subtypes showed poorer RMET performance compared to cognitively normal participants, consistent with our hypothesis and previous research (Bora & Yener, 2017; Moreau et al., 2015). Participants with multi-domain MCI may exhibit poorer RMET performance due to more severe cognitive impairment with more widespread neurodegeneration than single-domain MCI (Whitwell et al., 2007). While both single-domain amnestic and non-amnestic MCI display cognitive impairment in a single cognitive domain, there may be greater ToM impairment in non-amnestic MCI due to focal neurodegeneration in core regions implicated in social cognition, compared to circumscribed regions involved in memory (Whitwell et al., 2007). Indeed, non-amnestic MCI is more likely to progress to non-Alzheimer's dementias such as FTD (Yaffe, Petersen, Lindquist, Kramer, & Miller, 2006) or dementia with Lewy bodies (Ferman et al., 2013), whereas amnestic MCI is more likely to progress to AD, with the former dementia types showing larger deficits in social cognition (Bora et al., 2015). Additionally, although previous studies have reported ToM impairments in amnestic MCI, these studies have commonly combined both single-domain and multi-domain amnestic MCI (Michaelian et al., 2019; Poletti & Bonuccelli, 2013). These reported impairments may thus be driven by multi-domain cases.

Both MCI and dementia were associated with poorer social functioning, supporting our hypotheses. MCI and dementia diagnoses predicted reduced social network size, and dementia was also associated with increased perceived loneliness. Although reduced social engagement and increased loneliness are risk factors for cognitive impairment in dementia (Fratiglioni, Wang, Ericsson, Maytan, & Winblad, 2000; Saito, Murata, Saito, Takeda, & Kondo, 2018), recent studies show that dementia progression may also lead to poorer social functioning and decline in social networks (Dyer, Murphy, Lawlor, Kennelly, & Study Group for the Nilvad, 2020). Inappropriate social behaviours, even in very early stages of dementia, may impair social

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Table 4. Associations between diagnostic category, RMET and measures of social function –- pooled estimates from imputed data set – B coefficient, (95% CI), p-values

	z-RMET	MCI (ref: CN)	Dementia (ref: CN)	MCI x *z*-RMET	Dementia x *z*-RMET	Female gender (ref: male)	Education (yrs)	Non-Caucasian (ref: Cauc.)	*z*-Neuroticism
Social network[a] size	−.00 (−.06, .05)	**−.21 (−.40, −.02)**	**−.90 (−1.38, −.42)**	.06 (−.12, .23)	−.07 (−.45, .30)	**.13 (.03, .23)**	−.01 (−.03, .02)	−.26 (−.57, .05)	**−.19 (−.24, −.13)**
	.940	***.030***	***<.001***	*.470*	*.700*	***.020***	*.590*	*.100*	***<.001***
Loneliness[a]	−.00 (−.01, .01)	.06 (−.09, .21)	**.36 (.06, .67)**	−.01 (−.04, .02)	**−.07 (−.14, −.00)**	.01 (−.01, .02)	.00 (.00, .01)	**.09 (.03, .14)**	**.06 (.05, .07)**
	.862	*.462*	***.019***	*.539*	***.041***	*.650*	*.072*	***.013***	***<.001***
Negative friend support[a]	−.03 (−.08, .03)	−.07 (−.28, .13)	−.23 (−.85, .39)	−.16 (−.37, .05)	.07 (−.55, .69)	**−.30 (−.41, −.19)**	**.03 (.01, .05)**	.25 (−.06, .56)	**.12 (.07, .18)**
	.381	*.498*	*.470*	*.135*	*.830*	***<.001***	***.018***	*.109*	***<.001***
(less) Positive friend support[a]	.00 (−.01, .01)	.05 (−.12, .22)	.01 (−.38, .40)	−.01 (−.04, .03)	.02 (−.06, .11)	**−.07 (−.09, −.05)**	.00 (−.00, .01)	.05 (−.01, .11)	**.02 (.01, .03)**
	.960	*.544*	*.959*	*.678*	*.572*	***<.001***	*.326*	*.112*	***.001***
Negative family support[a]	.05 (−.01, .10)	−.02 (−.23, .18)	−.33 (−.90, .23)	−.14 (−.33, .06)	−.34 (−.79, .12)	−.09 (−.20, .02)	**.04 (.02, .06)**	.23 (−.10, .55)	**.13 (.07, .18)**
	.098	*.840*	*.250*	*.160*	*.144*	*.109*	***<.001***	*.168*	***<.001***
(less) Positive family support[a]	−.01 (−.02, .01)	−.04 (−.18, .11)	−.03 (−.37, .30)	.01 (−.02, .04)	.01 (−.07, .08)	−.00 (−.02, .02)	**.01 (.00, .01)**	−.04 (−.08, .00)	**.02 (.01, .03)**
	.421	*.637*	*.855*	*.515*	*.895*	*.836*	***<.001***	*.074*	***<.001***
Negative partner support[b]	.04 (−.03, .11)	.11 (−.13, .35)	−.07 (−.64, .50)	.12 (−.11, .35)	**−.37 (−.74, .00)**	.01 (−.12, .13)	.01 (−.02, .03)	**.60 (.22, .97)**	**.20 (.14, .26)**
	.228	*.372*	*.815*	*.289*	***.050***	*.936*	*.565*	***.002***	***<.001***
(less) Positive partner support[b]	−.00 (−.01, .01)	−.10 (−.26, .06)	.07 (−.11, .25)	.02 (−.01, .06)	−.02 (−.06, .02)	**.08 (.05, .10)**	.00 (−.00, .00)	**.09 (.01, .17)**	**.02 (.01, .03)**
	.992	*.228*	*.442*	*.232*	*.301*	***<.001***	*.879*	***.026***	***.001***

Note: CN = cognitively normal, MCI = mild cognitive impairment, RMET = Reading the Mind in the Eyes test.
[a]Imputed: $N = 1427$ (1272 cognitively normal, 23 dementia, 132 MCI); [b]Imputed: $N = 995$ (887 cognitively normal, 16 dementia, 92 MCI).

functioning (Henry et al., 2012). Although more common in rarer dementias, behaviours such as disinhibition, social awkwardness, and apathy, are also present in AD, which constitute a large proportion of our dementia sample (Desmarais, Lanctôt, Masellis, Black, & Herrmann, 2018). The reduced social network and increased subjective loneliness in populations with cognitive impairment may indicate a lack of social and emotional fulfilment. Although others have reported that better performance on ToM measures correlates with smaller 'close' social networks (Radecki et al., 2019), the Lubben scale of social network size used in our study did not capture the quality or closeness of those social relationships. Furthermore, for those with MCI and dementia, close networks may be harder to achieve due to reduced social cognition and social functioning, as suggested by our results. This may have further implications for their health and well-being. Loneliness, in particular, significantly reduces the quality of life in older adults and is linked to increased stress, depression, disability, and mortality (Berg-Weger & Morley, 2020; Zhu, Liu, Qu, & Yi, 2018).

In partial support of our hypothesis, RMET performance was associated with impaired social functioning in dementia but not MCI. It is noteworthy that this is the first time the association between ToM and social functioning has been explored in MCI and dementia populations. Specifically, in dementia, lower RMET performance was associated with reports of greater perceived loneliness and a trend towards more negative interactions with partners when they lived together, although this was not statistically reliable possibly due to the small number of participants with dementia. In dementia, impaired ToM may manifest as anosognosia, loss of insight, inability to infer others' thoughts and feelings, and offensive comments (Desmarais et al., 2018), which may result in less fulfilling social interactions and greater perceived loneliness and negative interactions. Additionally, effects were not apparent for non-partner social interactions. This may reflect differences in the degree and regularity of contact in comparison to social interactions with partners, particularly for participants with dementia, for whom partners may have assumed greater care-giving roles. Further work is required to confirm the reliability of this association.

On the other hand, in MCI, RMET performance was not associated with social functioning. It is likely that social functioning is supported by multiple cognitive abilities including expressive and receptive language, memory, and reasoning, and these cognitive factors may play a greater role in social functioning in early stages of cognitive decline. Consistent with this interpretation, the interaction effects found for dementia were quite small or marginally significant. Indeed one study reported that informant-rated socially inappropriate behaviours were more likely to be observed in dementia than participants who were cognitively healthy or had MCI (Henry et al., 2012) and that the social inappropriateness in dementia was associated with level of verbal memory impairment. These findings in combination suggest that while reductions in social network size are observable at early stages of cognitive decline (possibly contributing to ongoing cognitive decline), increasing social-cognitive deficits with dementia progression may contribute to increased loneliness and negative social interactions. Our results highlight the potential benefits of social-cognitive training for people with dementia (Hooker et al., 2013), in addition to other cognitive and behavioural compensatory techniques that enable greater social engagement (Kindell, Keady, Sage, & Wilkinson, 2017). Furthermore, it may be important to educate family and friends about the effects of dementia on social functioning to support positive social interactions. Prior studies in FTD samples have demonstrated the impact of impaired social cognition on functioning and particularly caregiver burden (e.g., Brioschi Guevara et al., 2015). Our findings add to this literature and suggest a need for wider examination of the social impacts of cognitive and behavioural impairments in dementia.

This study has some limitations. First, the study used a single, static measure of ToM (the RMET), which although easier to administer in an epidemiological setting, measures only affective ToM, and does not assess other aspects of social cognition such as complex emotional perception (Miguel, Caramanico, Huss, & Zuanazzi, 2017). Other measures, such as false-belief tasks, also have stronger associations with social functioning and interactions (Bora, Eryavuz, Kayahan, Sungu, & Veznedaroglu, 2006; Frith, 1994). These limitations may have led to an underestimation of associations between ToM and social function in MCI and dementia in our study. Performance on the RMET is also confounded by other aspects of cognition, such as vocabulary (Olderbak et al., 2015), which we sought to address by adjusting for education. Our study also did not address potential differences in the quality of social functioning across various types and levels of cognitive impairment. Second, most of our dementia sample was of AD nature as our study used a population-based sample. This may explain the weak associations between RMET and social functioning in dementia, as AD shows modest ToM deficits compared to other syndromes such as behavioural variant FTD (Bora et al., 2015). Additionally, exclusion of participants with neurocognitive diagnoses that did not meet DSM-IV criteria for dementia may have further biased the sample towards AD. Furthermore, the statistical models accounted for only a small degree of variance in social functioning measures, possibly because we did not include other important variables such as living environment, lack of purpose, and boredom (Cohen-Mansfield, Hazan, Lerman, & Shalom, 2016). Finally, the present study used cross-sectional data as there was only one wave of RMET data available. Thus, the causal relationship between impaired social cognition and social functioning in MCI and dementia could not be directly examined.

In conclusion, this study found significantly impaired RMET performance in both MCI and dementia. People with MCI and dementia reported reduced social network size, and people with dementia also reported greater perceived loneliness. Importantly, we demonstrate that ToM deficits, as measured by the RMET, are associated with impaired social

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functioning in dementia but not MCI. It may be important to address potential social cognitive deficits when supporting social engagement and positive interactions for people with dementia, surrounding family and friends. Future research should include a range of measures of social cognition, particularly with longitudinal observations to explore the causal relationship between social cognition and social functioning in MCI and dementia populations.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/S1355617721000898

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CONFLICTS OF INTEREST

None.

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